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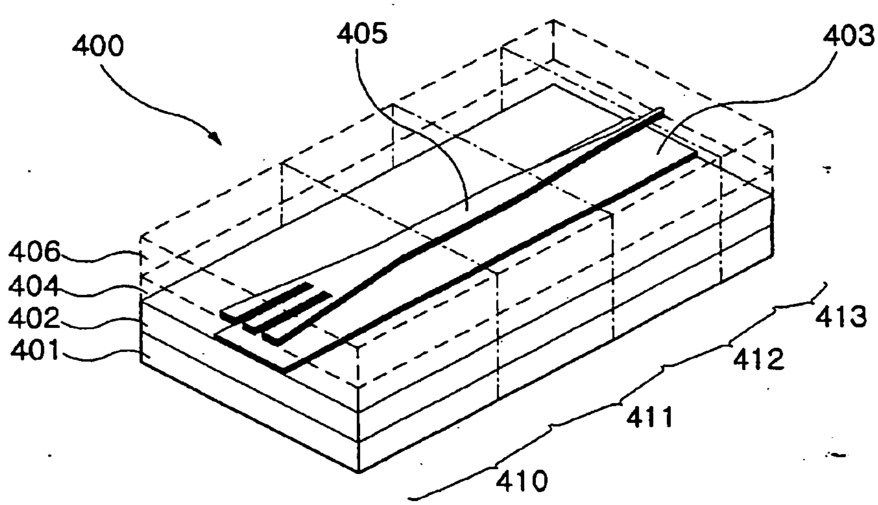
(54) Title: OPTICAL MODE SIZE CONVERTER



(57) Abstract: A optical mode size converter may increase alignment error allowance in an optical input unit combined with a semiconductor optical element as well as in an optical output unit combined with an optical fiber. The optical mode size converter positioned between a semiconductor light source and an optical transfer medium for receiving output light from the light source, converting its size and outputting includes a substrate, a buffer layer laminated on the substrate, a lower waveguide formed on a predetermined area on the buffer layer, a lower clad layer formed on the lower waveguide and the buffer layer, an upper waveguide formed on the lower clad layer corresponding to the lower waveguide and having a branched optical input unit, and an upper clad layer formed on the upper waveguide and the lower clad layer.

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OPTICAL MODE SIZE CONVERTER

TECHNICAL FIELD

The present invention relates to an optical mode size converter adopted to the optical communications, and more particularly to an optical mode size converter, which may decrease optical loss due to the combination between an optical element and an optical fiber by improving a light input unit of the optical mode size converter combined with the optical element using a III-V compound semiconductor such as a compound optical waveguide element, a laser diode, a semiconductor optical amplifier, a waveguide-type optical detector and so on.

BACKGROUND ART

Generally, a flush type semiconductor laser having characteristics of low oscillation threshold current and high quantum efficiency is used as a light source of an optical communication system. An output light of the flush type semiconductor laser has a shape of Fourier transformation of a basic optical mode formed in a structure of an active layer. At this time, though this basic mode has a small size of about 1.5~2μm, because an output light by the Fourier transformation of the basic mode has a very wide emission angle of 28~32 deg., the mode size may be significantly increased depending on its progressing

distance. However, a signal mode optical fiber used as an light signal transfer medium has a circular basic mode with an optical mode size of 9~10μm and a small N.A. (Numerical Aperture) is receivable for the signal mode optical fiber. Therefore, the light signal having a wide emission angle output from the light source cannot progress a long distance but disappeared as a loss though combined in the optical fiber because high-level modes are deserted in the signal mode optical fiber. For this reason, when the optical fiber and the semiconductor laser element are directly optically combined, there are caused a lot of optical losses due to the mode discordance. In this point, there have been proposed various measures for solving problems caused by combining the light and the optical fiber, such as by increasing a size of the basic optical mode of the output light to decrease an emission angle, making a light source element having an optical mode in a shape similar to an optical fiber, or deforming a shape of the light output from the light source to be combined with the optical fiber in an ideal state.

First, there is a method of reducing an emission angle of the light output from the light source by increasing a size of the basic mode of the output unit through structural deformation of the output unit of a semiconductor laser element (diode) used as the light source. This method, as shown in FIGs. 1a and 1b, uses a spot size converter LD (laser diode) having an optical mode converter. That is, this method

forms sections having a function of enlarging the optical mode size at the light output unit of the laser diode, in other words, forms tapering sections 101, 101' around active sections 105, 105' so as to make the mode size of the output light larger, so enlarging the basic mode size in a Fourier transformation relation with the emission angle to therefore reduce mismatch between the optical modes, and so reducing the emission angle as much as about 10 deg. to decrease the loss of light. FIG. 1a shows an optical mode converting manner using a vertical tapering structure, while FIG. 1b shows an optical mode converting manner using a lateral tapering structure, and each manner converts from a basic mode exciting condition to a leaky mode exciting condition toward only one direction. The active layer generally has a rectangular shape, and these manners promote the light combining efficiency by adjusting a length of one of two directions to make the basic mode size bigger and at the same time intentionally makes an oval mode shape of the output light into a circle, which is a shape of the optical mode of the optical fiber.

However, though there are accomplished various attempts, these manners are not proved to have reliability of the element so that it is hardly applied to the optical communications, which requires high reliability.

Secondly, in order to deform an end of the optical fiber receiving

the light, there is a method of collimating the light signal by tapering the edge or making the edge into a lens, or by using a lens. That is, there are various manners of attaching a GRIN (Graded Index) lens 203 to the edge of the optical fiber 201 to collimate the light output from the semiconductor laser element 202 as shown in FIG. 2a, tapering the edge of the optical fiber 201 as shown in FIG. 2b, or making a core 201c of the optical fiber 201 into a lens. In addition, as shown in FIG. 2d, a ball lens 204 may be positioned between the optical fiber 201 and the semiconductor laser element 202 to improve the optical combining efficiency.

However, this second method has very small alignment tolerance in a perpendicular direction to an light axis, so there is a problem of being accompanied with significant time and costs for executing an alignment process between the light source element and the optical fiber.

A third method, as shown in FIG. 3, employs a manner of preparing an optical mode size converter 303 as a passive component for converting a size of the optical mode output from the semiconductor laser element 301 into a size corresponding to the optical fiber 302, and arranges the optical mode size converter 303 between the semiconductor laser element 301 and the optical fiber 302. According to this method, an optical mode 301m outputted from the

semiconductor size converter 303 is incident on the optical mode size converter 303 to be converted into an optical mode 303m having a sufficiently big size, and then incident on an optical fiber core 302c. At this time, the difference between sizes of the optical mode size converter 303 and the optical fiber core 302c is reduced, so thereby decreasing the loss of light due to mismatch of the optical mode sizes. Reference numeral 303a denotes a substrate, reference numeral 303b denotes a buffer layer, reference numeral 303c denotes a cover layer, reference numeral 304 denotes an upper waveguide, and reference numeral 305 denotes a lower waveguide, respectively.

However, such a conventional optical mode size converter 303 is designed to have sufficient alignment tolerance for a portion combined with the optical fiber 302, but a portion combined with the semiconductor laser element 301 is designed without consideration of the light loss and the alignment tolerance. Therefore, though it may be seen that the light loss due to the mode mismatch in combining the light output from the light source with the optical mode size converter having an approximately same shape is less than the case of combining the light source and the optical fiber, because active layers of input units of the light source element and the optical mode size converter have very small width of about 1.0~1.5μm, the alignment tolerances for the horizontal and vertical directions are very small in the light

combination. Therefore, in consideration of the light combination in the overall processes that the light output from the semiconductor laser element 301 becomes incident on the optical fiber 302 through the optical mode size converter, there are problems that the overall combining efficiency is deteriorated because a combining efficient between the light source element and the optical mode size converter is decreased and the alignment tolerance is very small.

DISCLOSURE OF INVENTION

The present invention is designed to overcome such problems of the prior art, and an object of the invention is to provide an optical mode size converter, which may increase the alignment tolerance not only at a light output unit combined with an optical fiber but also at a light input unit combined with a semiconductor light element.

In order to accomplish the above object, the present invention provides an optical mode size converter positioned between a semiconductor light source and an optical transfer medium for receiving light output from the light source, converting a size of an optical mode of the output light and outputting the size-converted light, which includes a substrate, a buffer layer laminated on the substrate, a lower waveguide formed at a predetermined area on the buffer layer, a lower clad layer formed on the lower waveguide and the buffer layer, an upper

waveguide formed on the lower clad layer in correspondence with the lower waveguide, the upper waveguide having a branched light input unit, and an upper clad layer formed on the upper waveguide and the lower clad layer.

In such a configuration, the upper waveguide may include an optical mode input section having the branched light input unit, an optical mode stabilizing section for stabilizing an unstable optical mode guiding through the optical mode input section, a lateral optical mode expanding section for combining the light passing through the optical mode stabilizing section to the lower waveguide so as to expand a lateral mode of the light, and an optical mode output unit for outputting the mode-expanded light together with the lower waveguide.

Also, the branched light input unit may include a channel waveguide at a center, and tapered waveguides formed spaced apart from both sides of the channel waveguide.

Preferably, the tapered waveguides are formed so that a width is gradually decreased from a light input end.

The lateral mode expanding section also preferably has a width gradually decreasing from one end to the other end.

In this case, the lower waveguide may be formed to have a constant width as a whole.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, aspects, and advantages of preferred embodiments of the present invention will be more fully described in the following detailed description, taken accompanying drawings. In the drawings:

FIGs. 1a and 1b show examples of a conventional semiconductor laser element in which an optical mode converter is prepared;

FIGs. 2a to 2d show various manners of deforming a light input end to improve a light combining efficiency according to the prior art;

FIG. 3 shows a configuration of a conventional optical mode size converter;

FIG. 4 shows a configuration of an optical mode size converter according to the present invention;

FIG. 5 is a plane view showing configurations of upper and lower waveguides of the optical mode size converter according to the present invention; and

FIG. 6 shows a relation between an alignment tolerance and a combining efficiency of the light combination by using the optical mode size converter according to the present invention and the light combination of the conventional direct combining method.

BEST MODES FOR CARRYING OUT THE INVENTION

Hereinafter, a preferred embodiment of the present invention is described in detail with reference to the accompanied drawings.

FIG. 4 shows a configuration of an optical mode size converter according to the present invention, which is positioned between the semiconductor light source element 301 (see FIG. 3) and the light transfer medium (optical fiber) 302 to receive an output light from the light source element 301 and convert a size of the optical mode. The optical mode size converter 400 of the present invention includes a substrate 401, a buffer layer 402, a lower waveguide 403, a lower clad layer 404, an upper waveguide 405 and an upper clad layer 406.

The substrate 401 is positioned at a lowest position of the structure to provide a base for forming other elements to be laminated thereon and support the completed structure laminated thereon.

The buffer layer 402 helps the lower waveguide 403 to smoothly guide the light owing to a reflective index different from that of the lower waveguide 403. And, in the process of making the structure, the buffer layer 402 acts for minimizing the light loss due to dispersion because of using only semiconductor materials, formed by crystal growth, for the light transfer in order to reduce the light loss caused by impurities, which probably exist on the substrate 401, and the buffer layer 402 blocks physical and chemical actions, which are probable on or between the lower clad layer 404 and the lower waveguide 403 to aid the lower

waveguide 403 and the lower clad layer 404 in growing.

At an input side, the lower waveguide 403 acts for increasing a combining coefficient between a channel waveguide 405c (see FIG. 5) positioned at a center of a branched light input unit formed at an optical mode input section 410 of the upper waveguide 405 and tapered waveguides 405t positioned at both sides of the channel waveguide 405c. Therefore, in spite of the short input section 410, the light signal combined with the tapered waveguides 405t may be easily combined to the channel waveguide 405c. In addition, at an output side, the upper waveguide 405 has a width less than the wavelength of light. Therefore, as the light power positioned on an upper surface is gradually combined to the lower waveguide 403 with the guided light being converted into a leaky mode, the lower waveguide 403 acts for converting a size of the overall optical mode by making a size of the optical mode be maintained to a shape of a basic mode in an optical waveguide shape related to both of the lower waveguide and the upper waveguide.

The lower clad layer 404 helps the light be smoothly guided by the lower waveguide 403 together with the buffer layer 402 owing to a refractive index different from that of the lower waveguide 403. At the same time, the lower clad layer 404 acts for vertically enlarging a size of the basic mode at the output side by maintaining the space between the upper and lower waveguides.

The upper waveguide 405 helps the light be smoothly guided with minimizing the loss of light even when the light output from the light source is incident deviated from the center, and converts the size of the optical mode in connection with the lower waveguide 403. This upper waveguide 405 has relatively higher difference in the refractive index with the buffer layer 402, compared with the lower waveguide 403. Most of the light power combined by such a higher difference progresses limited to the upper waveguide during maintaining a constant width. However, from the point that the width is smaller than the wavelength of progressing light, the mode of the light signal becomes slowly bigger and bigger, and at the output side, the upper waveguide 405 makes the optical mode be maintained in a relatively bigger size in connection with the lower waveguide.

The upper clad layer 406 helps the light be smoothly guided by the upper waveguide 405 together with the lower clad layer 404 owing to a refractive index different from that of the upper waveguide 405.

The branched light input unit of the upper clad layer 406, as shown in FIG. 5, has light input ends branched to three parts, while the other end is united together again. Particularly, among three branches, the channel waveguide 405c at a center has a rectangular shape with a constant width, while the waveguides 405t at both sides of the channel waveguide 405c have a tapered shape in which the width is gradually

decreased backward, compared with the width of the light input end.

Moreover, the upper waveguide 405 is comprised of, on the basis of the light passage, the optical mode input section 410 having the branched light input unit, an optical mode stabilizing section 411 for stabilizing the optical mode, which has an unstable optical mode distribution guided through the optical mode input section 410, a lateral optical mode expanding section 412 for combining the light guided through the optical mode stabilizing section 411 to the lower waveguide 403 to be laterally expanded, and an optical mode output unit 413 for outputting the mode-expanded light together with the lower waveguide 403. At this time, the lateral optical mode expanding section 412 has a tapered shape, of which a width is gradually decreased from one end to the other end like the tapered waveguide 405t of the branched light input unit.

Now, operations of the optical mode size converter according to the present invention as constructed above are described in detail.

As described above, the optical mode size converter of the present invention is positioned and used between the semiconductor laser element 301 (see FIG. 3) and the optical fiber 302.

If the light output from the semiconductor laser element 301 is input to the center of the optical mode input section 410 of the optical mode size converter 400 according to the present invention, the light

signal is combined to the channel waveguide 405c of the optical mode input section 410. This light signal is stabilized in the basic mode and then progressed.

And, when a light signal is emitted from the semiconductor laser element 301, the light signal has an oval shape with a big emission angle of about 28~32 deg. because the basic mode has a small size of about 1~1.5μm. If the light (light signal) is incident with being deviated from the center of the optical mode input section 410, the light signal is combined with the tapered waveguides 405t of the optical mode input section 410. This light signal is then gradually converted to the leaky mode due to the limitation of the decreasing width of the tapered waveguide as it progresses through the tapered waveguide 405t, so that the light power is radiated from the waveguide. This radiated light power is therefore slowly combined with the waveguide 405c at the center. At this time, because the lower waveguide 403 acts as a waveguide of the radiated light wave source, the lower waveguide 403 helps the light be more easily transferred to the channel waveguide at the center, not vanished as a light loss, so improving the combining coefficient between two waveguides. Owing to this configuration, it is possible to obtain characteristics with a relatively short light input section, identically to those obtained from an element having a long light input section. And, as a result, it is also possible to reduce an

overall length of the element.

For that reason, as the light signal combined to the channel waveguide 405c at the center passes the stabilizing section 411, higher mode is removed and the light signal gets to have more stabilized signal mode shape. The light signal passing through the optical mode stabilizing section 411 then progresses in the leaky mode through the tapered waveguide of the lateral optical mode expanding section 412 because of its decreasing width, and the light power is radiated from the waveguide and then combined with the lower waveguide 403. Accordingly, the size of the optical mode maintains the state laid on between the upper and lower waveguides, while the vertical size of the optical mode becomes similar to a thickness of the lower clad layer and the lateral size of the optical mode gets bigger as much as a width of the lower waveguide 403. The light signal converted as above is then output from the optical mode output unit 413 and an output end of the lower waveguide 403. At this time, because the mode size of the output light signal has a Fourier transformation shape of a basic mode, it is possible to obtain a converted optical mode having a size approximately identical to a size of the optical mode of the optical fiber 302. The optical mode enlarged as above has a small emission angle as much as 10 deg. (as the optical mode size increases, the emission angle becomes relatively decreased), which reduces the light loss caused

by the mode size mismatch when combining with the optical fiber 302, so resultantly ensuring high combining efficiency and high alignment tolerance to lateral and vertical directions.

On the other hand, FIG. 6 shows a relation between an alignment tolerance and a combining efficiency of the light combination by using each of the optical mode size converter according to the present invention and the light combination of the conventional direct combining method.

In FIG. 6, reference numeral 601 denotes a graph showing the combining efficiency of the optical mode size converter of the present invention, while reference numeral 602 denotes a graph showing the combining efficiency in case of directly combining the light source element and the optical fiber. In order to obtain the light combining efficiency characteristic, the photoelectric wave manner and the effective refractive index manner are used.

As shown in FIG. 6, it can be seen that the value of the combining efficiency characteristic graph 601 of the optical mode size converter according to the present invention is to the maximum 14% higher than the value of the combining efficiency characteristic graph 602 of the conventional direct combination between the semiconductor light source element and the optical fiber within the alignment tolerance of about 2.5μm. Therefore, it would be easily understood that, within the

same alignment tolerance, the optical mode size converter of the present invention gives better combining efficiency than the conventional direct combination between the semiconductor light source element and the optical fiber, on the whole, and it would be also understood that this alignment tolerance can be expanded.

As a result, it can be seen that the optical mode size converter of the prevent invention gives better light combining efficiency and alignment tolerance due to structural improvement of the input unit.

INDUSTRIAL APPLICABILITY

As described above, the optical mode size converter according to the present invention has, except the channel waveguide at the center of the light input unit combined with the light source element, two tapered waveguides at both sides of the channel waveguide, so easily aligning the optical mode toward the center though the light output from the light source element is incident with being deviated from the center, thereby ensuring high alignment tolerance at the light input unit when the light output from the light source element is input to the optical mode size converter. And, as a result, the present invention may dramatically reduce the light loss in the overall light combining process that the output light from the light source element is transferred to the optical fiber through the optical mode size converter,

and thereby increase the alignment tolerance.

The present invention is not intended to be limited to the embodiment herein, but various modifications and changes will be readily apparent to those skilled in the art within the scope of the present invention, which is set forth in the appended claims.

What is claimed is:

1. An optical mode size converter positioned between a semiconductor light source and an optical transfer medium for receiving light output from the light source, converting a size of an optical mode of the output light and outputting the size-converted light, comprising:

a substrate;

a buffer layer laminated on the substrate;

a lower waveguide formed at a predetermined area on the buffer layer;

a lower clad layer formed on the lower waveguide and the buffer layer;

an upper waveguide formed on the lower clad layer in correspondence with the lower waveguide, the upper waveguide having a branched light input unit; and

an upper clad layer formed on the upper waveguide and the lower clad layer.

2. The optical mode size converter as claimed in claim 1, wherein the upper waveguide includes:

an optical mode input section having the branched light input unit,

an optical mode stabilizing section for stabilizing an unstable optical mode guiding through the optical mode input section,

a lateral optical mode expanding section for combining the light passing through the optical mode stabilizing section to the lower waveguide so as to expand a lateral mode of the light, and

an optical mode output unit for outputting the mode-expanded light together with the lower waveguide.

3. The optical mode size converter as claimed in claim 2, wherein the branched light input unit includes:

a channel waveguide at a center, and

tapered waveguides formed spaced apart from both sides of the channel waveguide.

4. The optical mode size converter as claimed in claim 3,

wherein the tapered waveguides are formed so that a width is gradually decreased from a light input end.

5. The optical mode size converter as claimed in claim 2,

wherein the lateral mode expanding section has a width gradually decreasing from one end to the other end.

6. The optical mode size converter as claimed in any of claims 1 to 5,

wherein the lower waveguide is formed to have a constant width as a whole.

FIG. 1a

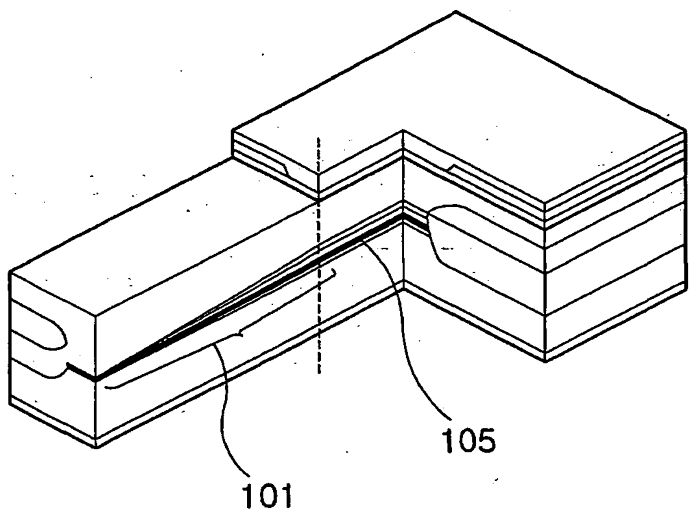

FIG. 1b

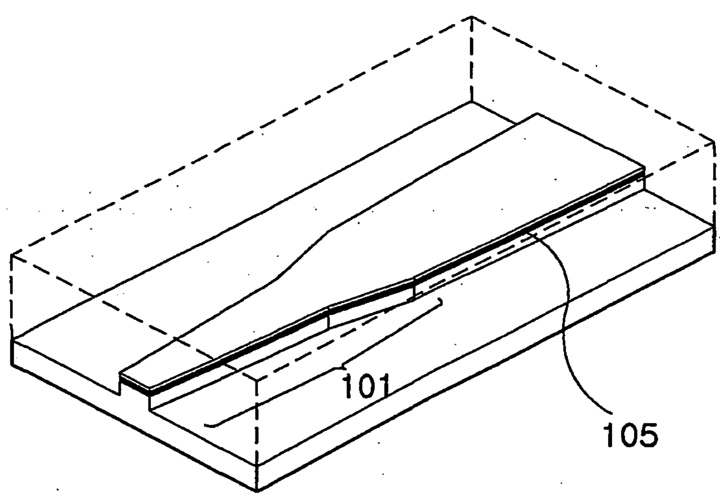

FIG. 2a

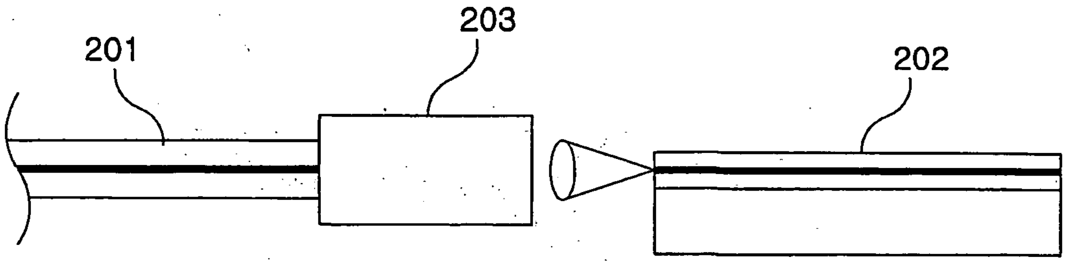

FIG. 2b

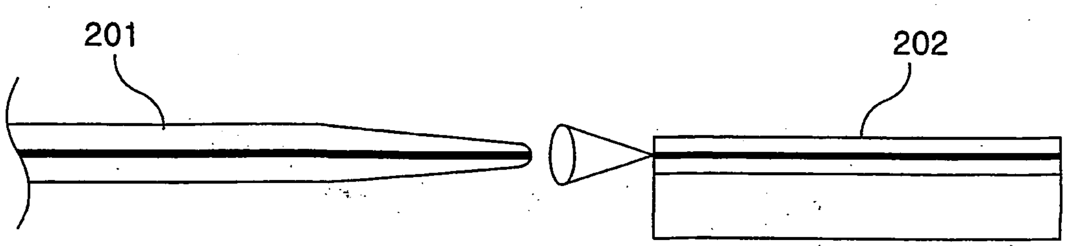

FIG. 2c

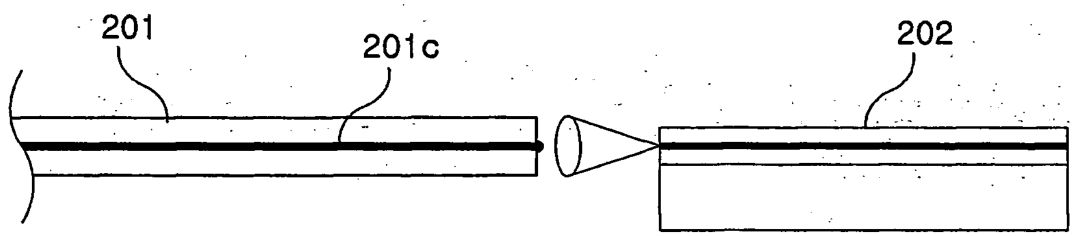

FIG. 2d

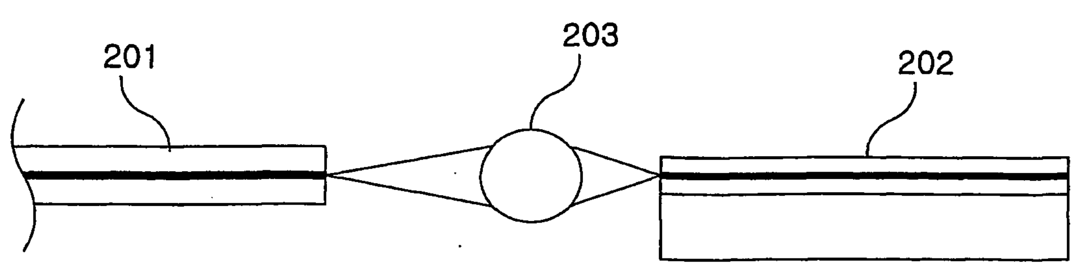

FIG. 3

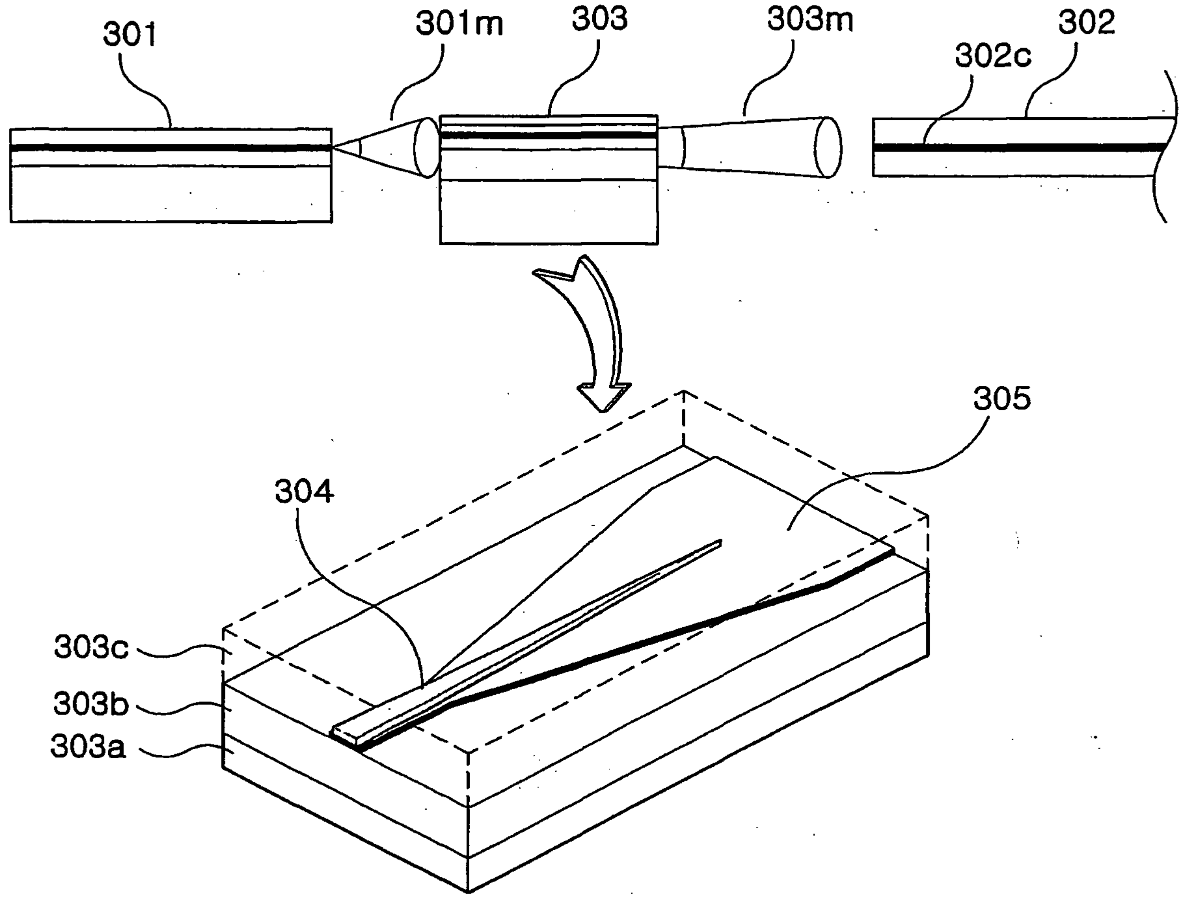

FIG. 4

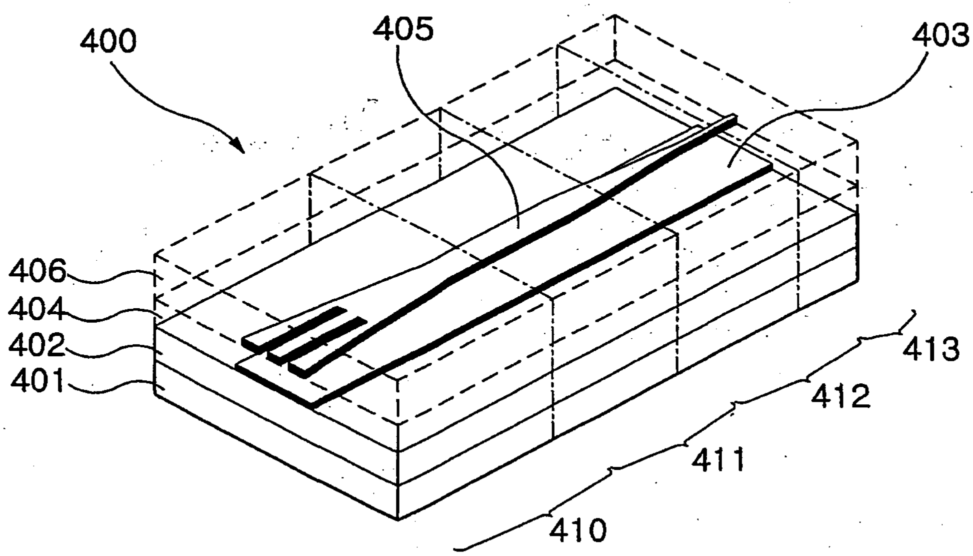
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FIG. 5

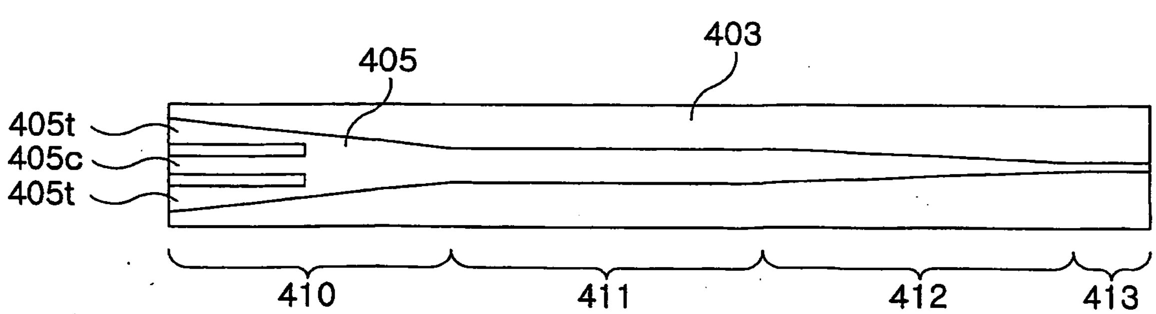
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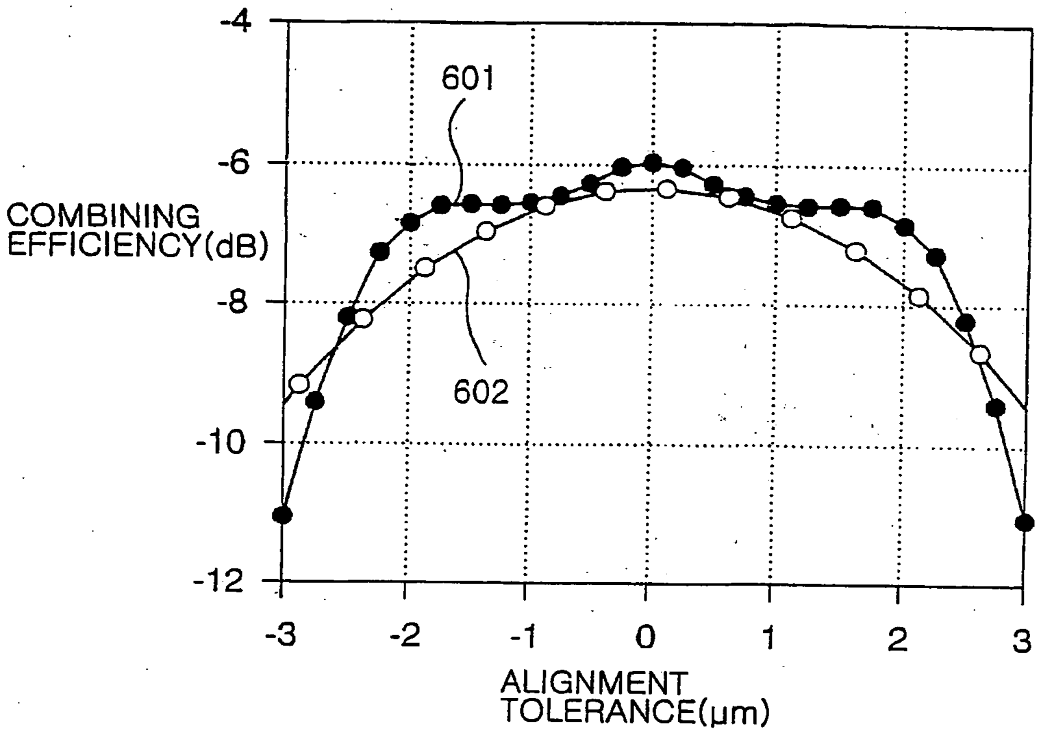
FIG. 6



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-2
-1
0
1
2
3
ALIGNMENT
TOLERANCE(μm)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR01/01652

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 H01L 31/12, G02B 6/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimun documentation searched (classification system followed by classification symbols)

IPC7 H01L, G02B, G02F

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Korean Patents and Applications for Inventions, since 1975
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Electronic data base consulted during the intertnational search (name of data base and, where practicable, search trerms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2-77731 A (SEIKO EPSON K.K.) 16 MARCH 1990 see the whole document	1-6
A	JP 3-219202 A (FUJITSU LTD.) 26 SEPTEMBER 1991 see the whole document	1-6
A	JP 4-159511 A (NEC CORP.) 2 JUNE 1992 see the whole document	1-6
A	JP 7-63935 A (NIPPON TELEGR & TELEPH CORP) 10 MARCH 1995 see the whole document	1-6
A	KR 1999-12248 A (SAMSUNG ELECTRONICS CO. LTD.) 25 FEBRUARY 1999 see the whole document	1-6

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Date of the actual completion of the international search	Date of mailing of the international search report
18 JANUARY 2002 (18.01.2002)	21 JANUARY 2002 (21.01.2002)

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INTERNATIONAL SEARCH REPORT
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